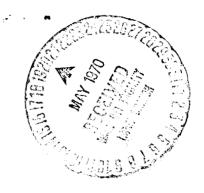BELLCOMM, INC.
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## COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Study of Four MSFN Configurations
for Coverage of 56 Day AAP Mission

TM- 69-2034-10

DATE- December 31, 1969

FILING CASE NO(S)- 900

AUTHOR(S)- J. P. Maloy

FILING SUBJECT(S)- MSFN Coverage for AAP
(ASSIGNED BY AUTHOR(S)-

(THRU)

(TEGORY)

### ABSTRACT

A study was made with the aid of a computer to de-
termine the optimum coverage provided by four combinations of
stations for an Apollo Applications Program (AAP) mission of
56 days duration.  The baseline network considered was the
Apollo 12 MSFN of 11 stations (Case 1).  Other alternatives
examined were:  (a) the Apollo 12 network without the three
85 foot antenna stations (Case 2), (b) the Apollo 12 network
with the addition of a station at Santiago (AGO) Chile (Case 3),
and (c) the Apollo 12 network minus the 85 foot stations, but
with a station at Santiago (Case 4).

Coverage data was collected for two versions of the
long duration AAP mission -- one at an orbital plane inclination
angle of 35° and the second at an inclination angle of 50°.  The
spacecraft altitude used was 235 nm and the elevation masking
assumed was a constant 5° for USB stations and 2° for VHF
stations.  For USB stations, a keyhole of 6° half-angle was
used for 30 foot stations and 15° half-angle for 85 foot
stations.  Also two cases of minimum acceptable station contact
were used, 3 and 5 minutes.

Results indicated that Santiago would clearly be an
asset to the station network since it is significantly effective
as a gap filler at both inclination angles for all combinations
of stations.  Its presence eliminates a large portion of gaps
in coverage of 90 minutes or more that would otherwise exist,
consequently saving much data that would have been lost.  With
the addition of a station at Santiago, the results show that
adding a VHF capability at the 85' MSFN stations would make an
insignificant change in the amount of VHF data lost (none at
35° inclination; 3 minutes at 50° inclination angle).

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BA-146 (8-64)

SUBJECT: Study of Four MSFN Configurations
for Coverage of 56 Day AAP Mission -
Case 900

DATE: December 31, 1969

FROM: J. P. Maloy

## TECHNICAL MEMORANDUM

A computer analysis was made of the communications
coverage provided by four different combinations of MSFN stations
(see Table 1) to determine the coverage for an AAP type mission
of 56 days duration, at an altitude of 235 nm.  The purpose of
the study was, in general, to see the effect on coverage of
(1) varying the number of stations in the network, (2) of changing
the inclination angle of the plane of the orbit (the two extremes
of 35° and 50° were used), (3) of different minimum station con-
tact times (3 and 5 minutes), and (4) of different station ele-
vation masking (2° and 5°).  More specifically this study was
meant to:

1) Determine the effect on coverage of a new station
   at Santiago, Chile (AGO).

2) Determine the additional VHF coverage obtained if
   VHF facilities were located at the three 85' antenna
   USB stations.

METHOD

A computer program designed to calculate line-of-sight
coverage was used to determine the number of contacts and con-
tact time for each MSFN station and the total accumulated unique
coverage of the network minus any contact time due to antenna
keyholes for the entire mission.  In addition, a subroutine
calculated the time between vehicle dropout from one station
to pickup of the next and printed out those that were ≥90 minutes.
This was done for the two orbital plane inclination angles of
35 and 50° and for the four combinations of stations as listed
in Table 1, considering 3 and 5 minutes as the minimum required
station contact time.  A constant elevation masking of 5° was
used when determining USB coverage, and a 2° elevation masking
was used for VHF.

The number of contacts and contact time for each
station for USB and VHF for the minimum station contact time
of 3 and 5 minutes during the 56 day AAP missions are tabulated
in Tables 3 through 6 and Tables 8 through 11.  Tables 16 through
21 contain gap information for the various combinations of stations,

inclination angles and minimum contact times.  Finally, Tables 22
and 23 contain percent coverage information provided in the various
cases as related to total mission time.

DISCUSSION

        The station coordinates used in this study are listed
in Table 2.  The same coordinates were used for USB and VHF
facilities since the relatively small difference in local
antenna locations was assumed to have negligible effect on the
overall results.  Table 3 shows a comparison of the number of
USB contacts acquired by each of the twelve stations considered
for 35° and 50° inclination angle, for a minimum contact time
of 3 minutes, with a 5° masking angle and appropriate keyhole
as indicated.  The stations are listed in decreasing order of
number of contacts for the 35° inclination case.  It is interesting
to note how this order changes with an inclination angle of 50°
as indicated in parentheses.  There is an average percent decrease
of 12.5% in the number of station contacts of 3 minutes or more,
but an increase for the Goldstone (GDS), Madrid (MAD), and
Honeysuckle (HSK) stations which are at the greater latitudes.

        Generally, there is the same pattern in Table 4 which
shows the total amount of USB contact time in minutes that each
station had over the 56 days.  The average decline in contact
time was greater, however, at 18.7% when going to the higher
inclination angle.

        Tables 5 and 6 show the same type of data when the
minimum contact is considered to be 5 minutes.  Here the number
of contacts and contact time lost is even greater on the average
when going from 35° to 50° (-19.5% and -22.8%, respectively).
A point of interest here is that for these parameters, there is
a direct relationship between a station's latitude and the
number of contacts obtained (see Table 13).  This may be useful
as an aid in determining the optimum location of a new station.

        Table 7 shows the magnitude of the decrease in the
number of contacts and in the total contact time when going
from the 3 minute minimum station contact duration to 5 minutes.
Generally, the decrease is greater at the 50° inclination orbit.
Guam (GWM) and Ascension (ACN), the two stations closest to the
equator, show a greater decrease at the 35° angle.

        Tables 8 through 12 show similar information for the
VHF coverage where a 2° constant elevation masking angle can
be assumed.  In all instances, as might be expected, the number
of contacts and contact times are greater than when the larger

USB masking angle of 5° was used.  Instead of having only three
stations (the three 85 foot antenna stations) show an increase
when the inclination angle of the orbital plane goes from 35°
to 50°, a total of five stations show an increase in the number
of contacts (see Tables 8 and 10).  AGO and Bermuda (BDA), the
next two highest in latitude, show significant increases, but
BDA does not show an increase in total contact time (see Tables 9
and 11) and neither does AGO in Table 11 when the minimum ac-
ceptable station contact time is 5 minutes.  A reasonable con-
clusion seems to be that the greater the latitude of the station
(within certain bounds of the inclination angle), the greater
will be the increase in number of contacts and contact duration
as the orbital inclination angle is increased, but as the mini-
mum permissible duration of the contact is increased, this
becomes less so.  In all cases, the average percent station
VHF coverage decrease in going to the higher inclination angle
is less than in the USB case.  Table 13 shows that those stations
at the higher latitudes have the greater number of VHF contacts
although there is a reversal of order in the first three places
among MAD, HSK and GDS.  Tables 14 and 15 show what the total
number of VHF contacts are for the networks listed in Table 1
for USB and VHF, and what the coverage differences are between
the two inclination angles.  Table 14 has the data for the 3
minute minimum contact condition and Table 15 contains the results
for 5 minute minimum contact time.

More significant, perhaps, than the number of contacts
and contact time is the number of gaps exceeding 90 minutes which
corresponds to the recording interval capability of the on-board
AAP recorder.  Tables 16 through 19 show the gaps in all cases
(4 USB, 4 VHF) and show the differences in the number and size
of gaps for the different inclination angles and minimum contact
times.  Tables 16 and 17 are a comparison of gaps by inclination
angle, whereas Tables 18 and 19 are a comparison for minimum
contact time.  Of course, the network with the least number of
stations (Case 2 has only 8 stations) has the greatest number
of these gaps, and the network with the greatest number of
stations (Case 3 has 12 stations) has the least number of gaps
of 90 minutes or more for the same inclination angle.  However,
VHF coverage for Case 2 at 35° inclination angle, for example,
has fewer of these gaps than Case 3 for a mission orbital plane
at a 50° inclination angle.

One very significant item that was revealed by this
type of analysis was the large proportion of gaps that are very
close to 90 minutes (90.0 to 92.5 min.).  These quantities are
indicated in parentheses.  If these could be eliminated by a
small increase in recording time or if this amount of lost data

were considered insignificant, then the number of gaps >90
minutes would be greatly reduced.  In all cases, the number
of significant gaps is greater at 50° inclination angle and
when the minimum contact time is 5 minutes.

A picture of which network provides better coverage is shown
in Tables 20 and 21.  In Table 20, the cases are arranged to
present the effect of adding a new station at Santiago,
Chile to the MSFN.  Cases 3 and 4, for USB and for VHF coverage,
respectively, are the ones where AGO is included and it can
readily be seen that AGO has a great influence at reducing
lost data time for both AAP orbital plane inclination angles.
Data is presumed to be lost when the gap between stations
exceeds the capability of the on-board recorder (90 minutes)
and the amount of lost data time is calculated by subtracting
90 minutes from the gap size.

When Santiago is added to the Apollo 12 network
(Case 1) at 35°, there are only 9 minutes of lost USB data
and these are accumulated from gaps 90.0 to 92.5 minutes
long.  Likewise, when AGO is in the network without the three
85 foot MSFN stations (Case 2) it makes a similar significant
reduction in lost data.  The amount of lost data in the VHF
coverage case for 35° inclination angle was insignificant
even without AGO.  When the minimum contact is considered
to be 5 minutes, AGO has an even more pronounced affect in
saving lost data for both the USB and VHF coverage cases.
Examination of the 50° inclination results shows that even
after the addition of AGO, more significant amounts of data
are still lost, but AGO makes a very large reduction by its
presence in the additional amount of data that otherwise would
have been lost.

Table 21 presents a similar analysis for the ef-
fectiveness of the three 85 foot USB stations in reducing
the amount of data lost.  Some consideration has been given
to the addition of VHF capability at these sites, but this
data indicates that this would contribute very little to
the amount of VHF coverage of the network when AGO is
included for either inclination angle or minimum contact time.
For VHF, Case 3 and 4, there is only a three-minute increase
in lost data when GDS, MAD and HSK are omitted at 50° incli-
nation angle for a 5 minute minimum station contact time.
For all other combinations of inclination angle and contact
time, these stations contribute nothing towards saving lost
VHF data.

Finally, the last two tables (22 and 23) show the
percent of unique coverage (non-overlapping with adjacent

stations) of each network for the various conditions of this study.  This measure in itself is not absolute and is only for comparison purposes and must be used in conjunction with other measures, such as the amount of lost data, to determine the efficiency of a network.  However, certain observations can be made, such as in all cases the percent of network coverage is reduced at the higher inclination angle.  The Case 3 network (12 stations) has the greatest percent coverage for all situations and Case 4 (9 stations), which presents a very good case from the point of view of gaps, ranks third.

CONCLUSIONS

There were some expected conclusions -- results that might have been intuitively determined, such as:

1) Coverage (number of contacts and duration of total contact time) would be greater at 35° than at 50° inclination angles of the AAP orbital plane.

2) There is greater coverage with more stations.

3) There is greater coverage for a 2° masking angle at all stations than for 5° for the same network.

4) There would be a greater number of gaps $\geq 90$ minutes when considering 5 minutes minimum station contacts vs. 3 minutes.

These expected relations were corroborated by this study and in addition:

1) A surprising number of gaps between 90 and 92.5 minutes were discovered (see Tables 16 through 20).

2) The amount of lost data due to gaps between stations exceeding 90 minutes was determined (see Tables 20 and 21).

3) The percent of unique (non-overlapping coverage between adjacent stations) coverage for each combination of stations was calculated (see Tables 22 and 23).

Two significant conclusions can be made:

1) A station at Santiago (AGO) would add significantly to the amount of data that could be collected (see Table 20).

2) The addition of a VHF capability at the 85 foot stations of GDS, MAD and HSK would add almost nothing to VHF coverage for the two inclination angles studied here (see Table 21).

J. P. Maloy

2034-JPM-drc

Attachment
Tables 1 thru 23

## TABLE 1

## DEFINITION OF CASES


Case 1: Apollo 12 Manned Space Flight Network:  Merritt Island (MIL), Bermuda (BDA), Grand Canary (CYI), Ascension (USB-ACN, VHF-ASC), Madrid (MAD), Carnarvon (CRO), Honeysuckle (HSK), Guam (GWM), Hawaii (HAW), Goldstone (GDS), Texas (TEX)

Case 2: Apollo 12 network minus the three 85 foot antenna stations at MAD, HSK and GDS.

Case 3: Apollo 12 network plus a new station at Santiago, Chile (AGO).

Case 4: Apollo 12 network minus the three 85 foot antenna stations at GDS, HSK and MAD, but plus AGO.

## TABLE 2

### STATION COORDINATES*

| Station | Longitude (°E) | Latitude (°) |
|---------|----------------|--------------|
| MIL | 279.3066 | 28.5083N |
| AGO | 290.0000 | 33.0000S |
| BDA | 295.3419 | 32.3506N |
| CYI | 344.3653 | 27.7644N |
| ACN-ASC | 345.6728 | 7.9547S |
| MAD | 355.8306 | 40.4550N |
| CRO | 113.7255 | 24.9066S |
| GWM | 144.7369 | 13.3106N |
| HSK | 148.9783 | 35.5837S |
| HAW | 200.3344 | 22.1264N |
| GDS | 243.1267 | 35.3417N |
| TEX | 262.6217 | 27.6539N |

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*The same coordinates were used for USB and VHF stations since the relatively small difference in antenna locations was assumed to have negligible effect on the results. These coordinates were taken from: Apollo 10/AS-505 MSFN Metric Tracking Performance, Preliminary, GSFC, 5/69.

# TABLE 3

## USB COVERAGE COMPARISON DATA
## FOR 35° AND 50° INCLINATION ANGLES
## AND CONTACTS >3 MIN.
### NUMBER OF CONTACTS

[56 day mission; alt.=235 nm; masking=5°; 6° keyhole for 30' ant.; 15° for GDS, MAD & HSK]

| | Sta. | Number of Contacts | | | Δ (50°-35°) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 393 | 218 | (10) | -175 | -44.5 |
| 2 | CRO | 372 | 228 | (9) | -144 | -38.7 |
| 3 | CYI | 352 | 244 | (7) | -108 | -30.7 |
| 4 | TEX | 351 | 243 | (8) | -108 | -30.8 |
| 5 | MIL | 344 | 249 | (6) | - 95 | -27.6 |
| 6 | BDA | 321 | 289 | (5) | - 32 | -10.0 |
| 7 | AGO | 313 | 298 | (4) | - 15 | - 4.8 |
| 8 | GDS | 292 | 369 | (1) | + 77 | +26.4 |
| 9 | HSK | 292 | 367 | (2) | + 75 | +25.7 |
| 10 | GWM | 280 | 195 | (11) | - 85 | -30.4 |
| 11 | ACN | 257 | 189 | (12) | - 68 | -26.5 |
| 12 | MAD | 243 | 345 | (3) | +102 | +42.0 |

Avg. % change per station in number of USB contacts from 35° to 50° incl. orbit = -12.5

( ) order of stations for most contacts for AAP mission using 50° inclination plane

## TABLE 4

### USB COVERAGE COMPARISON DATA
### FOR 35° AND 50° INCLINATION ANGLES

### AND CONTACTS $\overline{>}$3 MIN.
### CONTACT TIME

[56 day mission; alt.=235 nm; masking=5°; 6° keyhole for 30' ant.; 15° for GDS, MAD & HSK]

|   | Sta. | Contact Time (Minutes) | | Δ (Minutes) | % Chg. |
|---|------|------|------|------|------|
|   |      | 35° | 50° | | |
| 1 | CRO | 2866 | 1631 (9) | -1235 | -43.1 |
| 2 | HAW | 2835 | 1562 (10) | -1273 | -44.9 |
| 3 | TEX | 2808 | 1738 (8) | -1070 | -38.1 |
| 4 | CYI | 2802 | 1751 (7) | -1051 | -37.5 |
| 5 | MIL | 2771 | 1775 (6) | - 996 | -35.9 |
| 6 | BDA | 2569 | 2034 (5) | - 535 | -20.8 |
| 7 | AGO | 2501 | 2098 (4) | - 403 | -16.1 |
| 8 | GDS | 2311 | 2503 (3) | + 192 | + 8.3 |
| 9 | HSK | 2295 | 2514 (2) | + 219 | + 9.5 |
| 10 | GWM | 2013 | 1401 (11) | - 612 | -30.4 |
| 11 | ACN | 1861 | 1354 (12) | - 507 | -27.2 |
| 12 | MAD | 1762 | 2684 (1) | + 922 | +52.3 |

Avg. % change per station in total contact time from 35° to 50° incl. orbit = -18.7

( ) order of stations for most contact time for AAP mission using 50° inclination plane

## TABLE 5

### USB COVERAGE COMPARISON DATA
### FOR 35° AND 50° INCLINATION ANGLES
### AND CONTACTS >5 MIN.
### NUMBER OF CONTACTS

[56 day mission; alt.=235 nm; masking=5°; 6° keyhole for 30' ant.; 15° for GDS, MAD & HSK]

| | Sta. | Number of Contacts | | | Δ (50°-35°) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 377 | 188 | (10) | -189 | -50.1 |
| 2 | CRO | 356 | 193 | (9) | -163 | -45.8 |
| 3 | CYI | 329 | 213 | (6) | -116 | -35.3 |
| 4 | TEX | 337 | 209 | (8) | -128 | -38.0 |
| 5 | MIL | 330 | 213 | (7) | -117 | -35.5 |
| 6 | BDA | 294 | 243 | (5) | - 51 | -17.3 |
| 7 | AGO | 285 | 254 | (4) | - 31 | -10.9 |
| 8 | GDS | 273 | 278 | (3) | + 5 | + 1.8 |
| 9 | HSK | 273 | 280 | (2) | + 7 | + 2.6 |
| 10 | GWM | 242 | 170 | (11) | - 72 | -29.8 |
| 11 | ACN | 222 | 164 | (12) | - 58 | -26.1 |
| 12 | MAD | 222 | 326 | (1) | +104 | +46.8 |

Avg. % change per station in number of USB contacts from 35° to 50° incl. orbit = -19.8

( ) order of stations for most contacts for AAP mission using 50° inclination plane

## TABLE 6

### USB COVERAGE COMPARISON DATA

### FOR 35° AND 50° INCLINATION ANGLES

### AND CONTACTS >5 MIN.

### CONTACT TIME

[56 day mission; alt.=235 nm; masking=5°; 6° keyhole for 30' ant.; 15° for GDS, MAD & HSK]

| | Sta. | Contact Time (Minutes) | | | Δ (Minutes) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | CRO | 2803 | 1489 | (9) | -1314 | -46.9 |
| 2 | HAW | 2781 | 1439 | (10) | -1342 | -48.1 |
| 3 | TEX | 2752 | 1599 | (8) | -1153 | -41.9 |
| 4 | MIL | 2713 | 1627 | (6) | -1086 | -40.0 |
| 5 | CYI | 2707 | 1626 | (7) | -1081 | -39.9 |
| 6 | BDA | 2459 | 1846 | (5) | - 613 | -24.9 |
| 7 | AGO | 2384 | 1922 | (4) | - 462 | -19.4 |
| 8 | GDS | 2234 | 2104 | (3) | - 130 | - 5.8 |
| 9 | HSK | 2221 | 2121 | (2) | - 100 | - 4.5 |
| 10 | GWM | 1859 | 1298 | (11) | - 561 | -30.2 |
| 11 | ACN | 1714 | 1251 | (12) | - 463 | -27.0 |
| 12 | MAD | 1679 | 2599 | (1) | + 920 | +54.8 |

Avg. % change per station in contact time from 35° to 50° incl. orbit = -22.8

( ) order of stations for most contacts for AAP mission using 50° inclination plane

# TABLE 7

## USB COVERAGE COMPARISON DATA

Decrease in Number of Contacts
and Contact Time When Going from
3 Min. to 5 Min. Minimum Contact Time
For 35° and 50° Inclination Angle

[56 day mission; alt.=235 nm; masking=5°; 6° keyhole for 30' ant.; 15° for
GDS, MAD & HSK]

| | Sta. | Number of Contacts | | Sta. | Contact Time (Mins.) | |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | 35° | 50° |
| 1 | HAW | 16 | 30 | CRO | 63 | 142 |
| 2 | CRO | 16 | 35 | HAW | 54 | 123 |
| 3 | CYI | 23 | 31 | TEX | 56 | 139 |
| 4 | TEX | 14 | 34 | MIL | 58 | 125 |
| 5 | MIL | 14 | 36 | CYI | 95 | 148 |
| 6 | BDA | 27 | 46 | BDA | 110 | 188 |
| 7 | AGO | 28 | 44 | AGO | 117 | 176 |
| 8 | GDS | 19 | 91 | GDS | 77 | 399 |
| 9 | HSK | 19 | 87 | HSK | 74 | 393 |
| 10 | GWM | 38 | 25 | GWM | 154 | 103 |
| 11 | ACN | 35 | 25 | ACN | 147 | 103 |
| 12 | MAD | 21 | 19 | MAD | 83 | 85 |

## TABLE 8

### VHF COVERAGE COMPARISON DATA
### FOR 35° AND 50° INCLINATION ANGLES

### AND CONTACTS >3 MIN.
### NUMBER OF CONTACTS

[56 day mission; alt.=235 nm; masking=2°]

| | Sta. | Number of Contacts | | | Δ (50°-35°) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 407 | 258 | (10) | -149 | -36.6 |
| 2 | CRO | 390 | 275 | (9) | -115 | -29.5 |
| 3 | TEX | 379 | 294 | (8) | - 85 | -22.4 |
| 4 | CYI | 374 | 296 | (7) | - 78 | -20.9 |
| 5 | MIL | 372 | 302 | (6) | - 70 | -18.8 |
| 6 | GWM | 342 | 231 | (11) | -111 | -32.5 |
| 7 | BDA | 337 | 399 | (1) | + 62 | +18.4 |
| 8 | AGO | 335 | 398 | (2) | + 63 | +18.8 |
| 9 | GDS | 315 | 388 | (3) | + 73 | +23.2 |
| 10 | HSK | 315 | 385 | (4) | + 70 | +22.2 |
| 11 | ASC | 315 | 221 | (12) | - 94 | -29.8 |
| 12 | MAD | 272 | 365 | (5) | + 93 | +34.2 |

Avg. % change per station in number of VHF contacts from 35° to 50° incl. orbit = -6.1

( ) order of stations for most contacts for AAP mission using 50° inclination plane

# TABLE 9

## VHF COVERAGE COMPARISON DATA
## FOR 35° AND 50° INCLINATION ANGLES
## AND CONTACTS $\overline{>}$3 MIN.
## CONTACT TIME

[56 day mission; alt.=235 nm; masking=2°]

| | Sta. | Contact Time (Minutes) | | | Δ (Minutes) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 3571 | 2116 | (10) | −1455 | −40.7 |
| 2 | CRO | 3545 | 2234 | (9) | −1311 | −37.0 |
| 3 | TEX | 3472 | 2392 | (8) | −1080 | −31.1 |
| 4 | CYI | 3463 | 2406 | (7) | −1057 | −30.5 |
| 5 | MIL | 3429 | 2449 | (6) | − 980 | −28.5 |
| 6 | BDA | 3148 | 3025 | (5) | − 123 | − 3.9 |
| 7 | AGO | 3092 | 3105 | (4) | + 13 | + .4 |
| 8 | GDS | 2886 | 3260 | (2) | + 374 | +13.0 |
| 9 | HSK | 2869 | 3255 | (3) | + 386 | +13.5 |
| 10 | GWM | 2779 | 1896 | (11) | − 883 | −31.8 |
| 11 | ASC | 2564 | 1824 | (12) | − 740 | −28.9 |
| 12 | MAD | 2311 | 3317 | (1) | +1006 | +43.5 |

Avg. % change per station in contact time from 35° to 50°
incl. orbit = -13.5

( ) order of stations for most contacts for AAP mission using 50°
inclination plane

# TABLE 10

## VHF COVERAGE COMPARISON DATA
## FOR 35° AND 50° INCLINATION ANGLES

## AND CONTACTS $\overline{>}$5 MIN.
## NUMBER OF CONTACTS

[56 day mission; alt.=235 nm; masking=2°]

| | Sta. | Number of Contacts | | | Δ (50°-35°) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 393 | 235 | (10) | -158 | -40.2 |
| 2 | CRO | 379 | 248 | (9) | -131 | -34.6 |
| 3 | TEX | 365 | 265 | (8) | -100 | -27.4 |
| 4 | CYI | 359 | 267 | (7) | - 92 | -25.6 |
| 5 | MIL | 358 | 272 | (6) | - 86 | -24.0 |
| 6 | GWM | 306 | 210 | (11) | - 96 | -31.4 |
| 7 | BDA | 324 | 325 | (5) | + 1 | + .31 |
| 8 | AGO | 320 | 340 | (4) | + 20 | + 6.25 |
| 9 | GDS | 301 | 377 | (1) | + 76 | +25.2 |
| 10 | HSK | 301 | 374 | (2) | + 73 | +24.2 |
| 11 | ASC | 285 | 201 | (12) | - 84 | -29.5 |
| 12 | MAD | 257 | 353 | (3) | + 96 | +37.4 |

Avg. % change per station in number of VHF contacts from 35° to 50° incl. orbit = -9.9

( ) order of stations for most contacts for AAP mission using 50° inclination plane

## TABLE 11

### VHF COVERAGE COMPARISON DATA
### FOR 35° AND 50° INCLINATION ANGLES
### AND CONTACTS >5 MIN.
### CONTACT TIME

[56 day mission; alt.=235 nm; masking=2°]

| | Sta. | Contact Time (Minutes) | | | Δ (Minutes) | % Chg. |
|---|---|---|---|---|---|---|
| | | 35° | 50° | | | |
| 1 | HAW | 3508 | 2024 | (10) | -1484 | -42.3 |
| 2 | CRO | 3500 | 2128 | (9) | -1372 | -39.2 |
| 3 | TEX | 3425 | 2273 | (8) | -1152 | -33.6 |
| 4 | CYI | 3397 | 2290 | (7) | -1107 | -32.6 |
| 5 | MIL | 3378 | 2328 | (6) | -1050 | -31.1 |
| 6 | BDA | 3087 | 2769 | (5) | - 318 | -10.3 |
| 7 | AGO | 3030 | 2849 | (4) | - 181 | - 6.0 |
| 8 | GDS | 2823 | 3215 | (2) | + 392 | +13.9 |
| 9 | HSK | 2809 | 3209 | (3) | + 400 | +14.2 |
| 10 | GWM | 2638 | 1813 | (11) | - 825 | -31.3 |
| 11 | ASC | 2453 | 1739 | (12) | - 714 | -29.1 |
| 12 | MAD | 2249 | 3267 | (1) | +1018 | +45.3 |

Avg. % change per station in contact time from 35° to 50°
incl. orbit = -15.2

( ) order of stations for most contacts for AAP mission using 50°
inclination plane

## TABLE 12

### VHF COVERAGE COMPARISON DATA

Decrease in Number of Contacts
and Contact Time When Going from
3 Min. to 5 Min. Minimum Contact Time
For 35° and 50° Inclination Angle

[56 day mission; alt.=235 nm; masking=2°]

| | Sta. | Number of Contacts | | | Sta. | Contact Time (Mins.) | |
|---|---|---|---|---|---|---|---|
| | | 35° | 50° | | | 35° | 50° |
| 1 | HAW | 14 | 23 | | HAW | 63 | 92 |
| 2 | CRO | 11 | 27 | | CRO | 45 | 106 |
| 3 | TEX | 14 | 29 | | TEX | 47 | 119 |
| 4 | CYI | 15 | 29 | | CYI | 66 | 116 |
| 5 | MIL | 14 | 30 | | MIL | 51 | 121 |
| 6 | GWM | 36 | 21 | | BDA | 61 | 256 |
| 7 | BDA | 13 | 74 | | AGO | 62 | 256 |
| 8 | AGO | 15 | 58 | | GDS | 63 | 45 |
| 9 | GDS | 14 | 11 | | HSK | 60 | 46 |
| 10 | HSK | 14 | 11 | | GWM | 150 | 83 |
| 11 | ASC | 30 | 20 | | ASC | 111 | 85 |
| 12 | MAD | 15 | 12 | | MAD | 62 | 50 |

## TABLE 13

## STATION LATITUDE VS CONTACTS (>5 MIN.)
### 50° INCLINATION ANGLE

| Station | Latitude (°) | Number of Contacts | |
|---------|--------------|--------------------|----|
|         |              | USB | VHF |
| MAD | 40.5N | 326 | 353 |
| HSK | 35.6S | 280 | 374 |
| GDS | 35.3N | 278 | 377 |
| AGO | 33.0S | 254 | 340 |
| BDA | 32.4N | 243 | 325 |
| MIL | 28.5N | 213 | 272 |
| CYI | 27.8N | 213 | 267 |
| TEX | 27.7N | 209 | 265 |
| CRO | 24.9S | 193 | 248 |
| HAW | 22.1N | 188 | 235 |
| GWM | 13.3N | 170 | 210 |
| ACN | 8.0S  | 164 | 201 |

## TABLE 14

### CASE COMPARISON

### 35° VS 50° INCLINATION ANGLE

### CONTACTS >̄3 MIN.

### NUMBER OF CONTACTS

| USB Case | 35° | 50° | Δ (50°-35°) | % Chg. |
|---|---|---|---|---|
| 1 | 3497 | 2935 | -562 | -16.1 |
| 2 | 2670 | 1855 | -814 | -30.5 |
| 3 | 3810 | 3233 | -577 | -15.1 |
| 4 | 2983 | 2153 | -829 | -27.7 |
| **VHF Case** | | | | |
| 1 | 3819 | 3414 | -405 | -10.5 |
| 2 | 2917 | 2276 | -641 | -22.0 |
| 3 | 4154 | 3812 | -342 | - 8.2 |
| 4 | 3252 | 2674 | -578 | -17.8 |

TABLE 15

CASE COMPARISON

35° VS 50° INCLINATION ANGLE

CONTACTS $\overline{>}$5 MIN.

NUMBER OF CONTACTS

| USB Case | 35° | 50° | Δ (50°-35°) | % Chg. |
|----------|------|------|-------------|--------|
| 1 | 3255 | 2477 | -778 | -23.9 |
| 2 | 2487 | 1593 | -894 | -35.9 |
| 3 | 3540 | 2731 | -809 | -22.9 |
| 4 | 2772 | 1847 | -925 | -33.4 |
| VHF Case | | | | |
| 1 | 3628 | 3127 | -501 | -13.8 |
| 2 | 2769 | 2023 | -746 | -26.9 |
| 3 | 3948 | 3467 | -481 | -12.2 |
| 4 | 3089 | 2363 | -726 | -23.5 |

## TABLE 16

## GAP SUMMARY FOR CONTACTS $\overline{>}$3 MIN.

| USB Case | Incl. Angle ° | Gap Size (Min.) 90-120 | 120-150 | 150-180 | 180-210 | Total Number |
|---|---|---|---|---|---|---|
| 1 | 35 | 109 (109) | 19 | – | – | 128 |
|   | 50 | 36 (36) | 43 | 18 | – | 97 |
| 2 | 35 | 176 (176) | 19 | – | – | 195 |
|   | 50 | 78 (62) | 47 | 50 | – | 175 |
| 3 | 35 | 14 (14) | – | – | – | 14 |
|   | 50 | 4 (4) | 43 | – | – | 47 |
| 4 | 35 | 69 (69) | – | – | – | 69 |
|   | 50 | 46 (23) | 47 | – | – | 93 |
| **VHF Case** | | | | | | |
| 1 | 35 | 7 (7) | – | – | – | 7 |
|   | 50 | 13 (13) | 27 | – | – | 40 |
| 2 | 35 | 10 (10) | – | – | – | 10 |
|   | 50 | 16 (16) | 27 | 30 | – | 73 |
| 3 | 35 | – | – | – | – | – |
|   | 50 | 27* | – | – | – | 27 |
| 4 | 35 | – | – | – | – | – |
|   | 50 | 27* | – | – | – | 27 |

( ) Gap Size = 90.0 to 92.5 Min.
 * Gap = 93.7 or 93.8 Min.

## TABLE 17

## GAP SUMMARY FOR CONTACTS >5 MIN.

| USB Case | Incl. Angle ° | Gap Size (Min.) | | | | | Total Number |
|---|---|---|---|---|---|---|---|
| | | 90-120 | 120-150 | 150-180 | 180-210 | 272.3 | |
| 1 | 35 | 135 (135) | 43 | – | – | – | 178 |
| | 50 | 22 (22) | 56 | 24 | 8 | – | 110 |
| 2 | 35 | 195 (195) | 43 | – | – | – | 238 |
| | 50 | 71 (34) | 77 | 48 | – | 8 | 204 |
| 3 | 35 | 43 (35) | – | – | – | – | 43 |
| | 50 | 3 (3) | 56 | – | – | – | 59 |
| 4 | 35 | 103 (103) | – | – | – | – | 103 |
| | 50 | 64 (8) | 77 | – | – | – | 141 |
| VHF Case | | | | | | | |
| 1 | 35 | 7 (7) | 7 | – | – | – | 14 |
| | 50 | 3 (3) | 37 | 9 | – | – | 49 |
| 2 | 35 | 17 (17) | 7 | – | – | – | 24 |
| | 50 | 12 (12) | 37 | 42 | – | – | 91 |
| 3 | 35 | – | – | – | – | – | – |
| | 50 | 37 (10)* | – | – | – | – | 37 |
| 4 | 35 | – | – | – | – | – | – |
| | 50 | 46 (8) (10)* | – | – | – | – | 46 |

( )  Gap Size = 90.0 to 92.5 Min.
( )* Gap = 93.7 or 93.8 Min.

## TABLE 18

## GAP COMPARISON - 5 MIN. VS 3 MIN. MINIMUM CONTACT

## 35° INCL. ANGLE

| USB Case | Contact Min. | Gap Size (Min.) 90-120 | 120-150 | 150-180 | 180-210 | Total Number |
|----------|--------------|------------------------|---------|---------|---------|--------------|
| 1 | 3 | 109 (109) | 19 | - | - | 128 |
|   | 5 | 135 (135) | 43 | - | - | 178 |
| 2 | 3 | 176 (176) | 19 | - | - | 195 |
|   | 5 | 195 (195) | 43 | - | - | 238 |
| 3 | 3 | 14 (14) | - | - | - | 14 |
|   | 5 | 43 (35) | - | - | - | 43 |
| 4 | 3 | 69 (69) | - | - | - | 69 |
|   | 5 | 103 (95) | - | - | - | 103 |

| VHF Case | | | | | | |
|----------|---|---------|---|---|---|---|
| 1 | 3 | 7 (7) | - | - | - | 7 |
|   | 5 | 7 (7) | 7 | - | - | 14 |
| 2 | 3 | 10 (10) | - | - | - | 10 |
|   | 5 | 17 (17) | 7 | - | - | 24 |
| 3 | 3 | - | - | - | - | - |
|   | 5 | - | - | - | - | - |
| 4 | 3 | - | - | - | - | - |
|   | 5 | - | - | - | - | - |

( ) Gap Size = 90.0 to 92.5 Min.

TABLE 19

## GAP COMPARISON - 5 MIN. VS 3 MIN. MINIMUM CONTACT

### 50° INCL. ANGLE

| USB Case | Contact Min. | Gap Size (Min.) | | | | | Total Number |
|---|---|---|---|---|---|---|---|
| | | 90-120 | 120-150 | 150-180 | 180-210 | 272.3 | |
| 1 | 3 | 36 (36) | 43 | 18 | – | – | 97 |
|   | 5 | 22 (22) | 56 | 24 | 8 | – | 110 |
| 2 | 3 | 78 (62) | 47 | 50 | – | – | 175 |
|   | 5 | 71 (34) | 77 | 48 | – | 8 | 204 |
| 3 | 3 | 4 (4) | 43 | – | – | – | 47 |
|   | 5 | 3 (3) | 56 | – | – | – | 59 |
| 4 | 3 | 46 (23) | 47 | – | – | – | 93 |
|   | 5 | 64 (8) | 77 | – | – | – | 141 |

| VHF Case | Contact Min. | 90-120 | 120-150 | 150-180 | 180-210 | 272.3 | Total Number |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 13 (13) | 27 | – | – | – | 40 |
|   | 5 | 3 ( 3) | 37 | 9 | – | – | 49 |
| 2 | 3 | 16 (16) | 27 | 30 | – | – | 73 |
|   | 5 | 12 (12) | 37 | 42 | – | – | 91 |
| 3 | 3 | 27 (27)* | – | – | – | – | 27 |
|   | 5 | 37 (10)* | – | – | – | – | 37 |
| 4 | 3 | 27 (27)* | – | – | – | – | 24 |
|   | 5 | 46 (8)(10)* | – | – | – | – | 46 |

( )  Gap Size = 90.0 to 92.5 Min.
( )* Gap = 93.7 or 93.8 Min.

## TABLE 20

### TO SHOW EFFECT OF STATION AT SANTIAGO (AGO)

### ON MINUTES OF DATA LOST

Example:  Gap between Contacts = 133.4 Min.
133.4 - 90.0* = 43.4 Min. Data Lost

| USB Case | Contacts >3 Min. | | Contacts >5 Min. | |
|---|---|---|---|---|
| | 35° | 50° | 35° | 50° |
| 1 | 916 ( 80.5) | 3585 (25.7) | 2112 ( 97.7) | 5271 ( 5.3) |
| 3 | 9 ( 9.0) | 1583 ( 2.6) | 191 ( 24.5) | 2348 ( .3) |
| 2 | 957 (121.9) | 7569 (53.6) | 2145 (136.0) | 9462 (10.6) |
| 4 | 27 ( 27.1) | 2575 (23.8) | 227 ( 60.7) | 4071 ( 2.6) |
| **VHF Case** | | | | |
| 1 | 1 ( .9) | 1172 ( 4.7) | 299 ( .9) | 2379 ( .6) |
| 3 | – | 98 | – | 835 |
| 2 | 1 ( .9) | 3747 ( 8.5) | 300 ( 2.4) | 5115 ( 3.4) |
| 4 | – | 98 | – | 838 ( 2.8) |

* Capacity of on-board tape recorder
( ) Accumulative lost time from gaps 90.0 to 92.5 minutes long

# TABLE 21

## TO SHOW EFFECT OF 85 FOOT ANTENNA STATIONS
## (GDS, MAD, HSK) ON MINUTES OF DATA LOST

Example:  Gap between Contacts = 133.4 Min.
          133.4 - 90.0* = 43.4 Min. of Data Lost

| USB Case | Contacts >̄3 Min. | | Contacts >̄5 Min. | |
|---|---|---|---|---|
| | 35° | 50° | 35° | 50° |
| 1 | 916 | 3535 | 2112 | 5271 |
| 2 | 957 | 7569 | 2145 | 9462 |
| 3 | 9 | 1583 | 191 | 2348 |
| 4 | 27 | 2575 | 227 | 4071 |
| **VHF Case** | | | | |
| 1 | 1 | 1172 | 299 | 2379 |
| 2 | 1 | 3747 | 300 | 5115 |
| 3 | – | 98 | – | 835 |
| 4 | – | 98 | – | 838 |

* Capacity of on-board tape recorder

## TABLE 22

## % NETWORK COVERAGE FOR 56 DAY MISSION
## FOR CONTACTS $\overline{>}$3 MIN.

| | USB | | | | VHF | | |
| | Incl. Angle | | | | Incl. Angle | | |
| Case | 35° | 50° | % Chg. | | 35° | 50° | % Chg. |
|------|------|------|--------|--|------|------|--------|
| 1 | 26.5 | 21.6 | -18.5 | | 32.9 | 28.3 | -14.0 |
| 2 | 22.0 | 14.4 | -34.5 | | 27.3 | 19.5 | -28.6 |
| 3 | 29.7 | 24.2 | -18.5 | | 36.7 | 32.1 | -12.5 |
| 4 | 25.2 | 17.0 | -32.5 | | 31.3 | 23.3 | -25.6 |

## TABLE 23

### % NETWORK COVERAGE FOR 56 DAY MISSION
### FOR CONTACTS $\overline{>}$5 MIN.

| | USB | | | VHF | | |
|---|---|---|---|---|---|---|
| | Incl. Angle | | | Incl. Angle | | |
| Case | 35° | 50° | % Chg. | 35° | 50° | % Chg. |
| 1 | 25.6 | 20.0 | -21.9 | 32.2 | 27.4 | -14.9 |
| 2 | 21.3 | 13.4 | -37.1 | 26.8 | 18.5 | -31.0 |
| 3 | 28.6 | 22.4 | -21.7 | 36.0 | 30.9 | -14.2 |
| 4 | 24.3 | 15.8 | -35.0 | 30.6 | 22.0 | -28.1 |